South American perspective of the International Charter "Space and Major Disasters"

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Abstract. The International Charter "Space and Major Disasters" is about joint operations and tasking of imaging satellites and other space resources of the member space agencies and operators in the delivery of information products to assist in responding to disasters of natural and technological causes. Authorized Users, who are the civil protection, emergency response or similar organizations of a state that is member of the Charter, can request the data and products. A specialist, called the Project Manager (PM), manages the overall data acquisition and delivery process. Regional initiatives, as for the Latin American countries, are under way to involve PMs from non-member states to have access to satellite data and apply these to disaster coverage in their respective regions. Volcanic eruptions are typical examples of disasters that affect the Latin American countries. A few Charter activations on this disaster type are described to highlight the information products provided under the Charter.

1 Introduction

The International Charter "Space and Major Disasters" is the first space-based operational initiative to provide fast and assured access to satellite data and services during emergencies caused by natural or technological disasters. The Charter concept was introduced at the last global space conference UNISPACE III, and since then space agencies from around the world have been making this concept an exciting reality. The Charter operations were established in November 2000 by the three founding members, namely the European Space Agency (ESA), the French Centre National d'Etudes Spatiales (CNES), and the Canadian Space Agency (CSA). The current membership of the Charter additionally includes the U.S. National Oceanic and Atmospheric Administration (NOAA) along with the U.S. Geological Survey (USGS), the Indian Space Research Organization (ISRO), the Argentinean Comision Nacional de Actividades Espaciales (CONAE), the British National Space Center (BNSC) and the Disaster Monitoring Constellation (DMC), the Japan Aerospace Exploration Agency (JAXA), and the China National Space Administration (CNSA).

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The uniqueness of the Charter lies in a single point of contact and a coordinated approach to space supported disaster relief offered by the Charter members. Data acquisitions from multiple sensors, both passive and active, onboard the participating satellites are carried out with high planning priorities, and information products are delivered with short turnaround through pre-identified users.

As a step in the evolving Charter operations, the authorities of the disaster-affected countries are being involved in managing the Charter events by means of various initiatives. A proposal to this effect is presently implemented in the countries of South and Central America. The proposal implementation provides for the training and certification of local staff to carry out the Project Manager's function, which is described below. The staff gets access to the satellite data and the opportunity to supervise the delivery of data and information products to the people working in the field. Of special interest to the South and Central American countries are the disasters caused by volcanic eruptions that are associated with the geotectonic setting of the region. Therefore, the paper is written with the purpose of briefly describing the Charter operational process and showing the type of data products specific to this disaster type.

2 Charter concept

The Charter implementation is the responsibility of a Charter Executive Secretariat (Mahmood et al., 1998) where each member that has assumed the full Charter operational

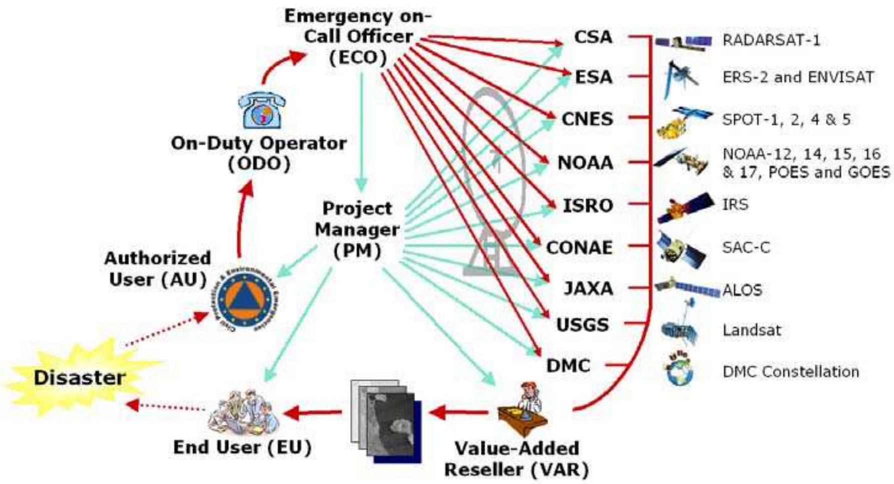

Fig. 1. Operational loop of the International Charter "Space and Major Disasters".

function is represented. The Executive Secretariat works under the overall responsibility of a Charter Board formed of all the members. The Charter business is conducted by regular conference calls of the Charter Executive Secretariat and the biannual Board meetings hosted in turn by the member agencies. The agency hosting a Charter Board meeting assumes the lead role and becomes the Charter point of contact until the following meeting. A well-structured ftp site serves as the Charter virtual secretariat for information exchange and repository. The Charter web (www.disasterscharter.org) is kept fully updated with the latest Charter activities and activations. The site also provides linkages to the Internet sites of the member agencies where detailed descriptions of the Charter members' space assets can be found, both in terms of the satellite missions and their payloads.

The purpose of the Charter is to promote cooperation among space agencies and space system operators in the use of their resources for making a contribution towards the management of crises arising from natural or technological disasters. The Charter covers the "response phase" of a disaster and the contributions of the member agencies are limited to satellite data at a predetermined processing level. Any value adding and information extraction from the data is at a member agency's own initiative with local or international parties.

The Charter can be activated by a group of predefined users for obtaining data covering a disaster event. These users are called "Authorized Users" (AUs). They are primarily institutions or services responsible for rescue and civil protection, defense and security under the authority of a State whose jurisdiction covers an agency or a space operator that is a member of the Charter. For the past three years, the United Nations agencies represented by the UN Office for the Outer Space Affairs (UN OOSA) have also been authorized to request the Charter data.

3 Charter operations

The Charter has been operational since 1 November 2000; it is in fact the first multi-satellite joint operational initiative. The operational system is illustrated in Fig. 1, and the roles of the various functional units involved have been detailed in Bessis et al. (2003) and Mahmood et al. (2005). The AU's request is received by a centralized 24 h/day call-receiving unit manned by an "On-Duty Operator" (ODO). This function is presently furnished by ESA at ESRIN in Frascati (Italy). After initial application of the request acceptance criteria, the ODO refers the request to the next functional unit named "Emergency on-Call Officer" (ECO), who is accessible 24 h a day. The ECO function is assumed on a weekly rotation by the member agencies. An important prerequisite for an agency to be totally integrated with the Charter operations is its ability to perform the ECO function, and as a consequence of which its participation in all the activities and responsibilities of the Executive Secretariat. The ECO carries out in-depth verification of the request by interaction with the AU and by using the ECO's own means of information on the reported disaster event, before the request is finally accepted for acquisition planning. The ECO prepares an elaborate record of the request, and determines the data source (archive or new acquisition) and space sensor(s) most appropriate to cover the disaster. The ECO checks the availability of the sensor(s), and suggests, whenever possible after discussions with the relevant space agency or its designate, a draft plan to the agency(ies) for execution. The ECO then transfers the entire file on the disaster occurrence, called a "Dossier", to a "Project Manager" (PM), who is appointed by the Executive Secretariat, after nomination by one of the agencies and by taking into account such factors as the geographical location of the disaster occurrence, its type, and the expertise required. The PM ensures the management of the project related to the coverage of the disaster and with regard to data processing and delivery. The PM through interaction with the AU complements the information needs of the requester and initiates, as the case may be, any special data product generation and value-adding on behalf of the concerned agency and beyond the agency's obligations under the Charter. The PM also provides a project closeout report to the Charter Executive Secretariat. In addition to the technical details, the report contains the PM's own experience with the activation and the end user feedback.

4 Charter activations

The Charter activations have been requested by the AUs to cover volcanic events spread all over the world; however, in order to showcase the typical satellite data products generated for covering the crisis response for this disaster type, the following cases of the Charter activation are briefly described. These are the eruptions of Etna in July 2001, Nyiragongo in January 2002, Montserrat in July 2003, Galeras in August 2004 and finally the Comoros in December 2005.

4.1 Etna, Italy

The 1st Charter activation over a volcanic eruption was requested on 26 July 2001, by the Italian Civil Protection to monitor the Etna eruption. Optical images from SPOT and Landsat, and Synthetic Aperture Radar (SAR) images from ERS-2 and RADARSAT-1 were processed for volcanic plume, thermal mapping, and ground deformation. Using Landsat thermal bands, overall thermal anomalies were mapped for two dates, in red for 21 July and in blue for 29 July, with regard to three temperature ranges, as shown in Fig. 2a. The thermal mapping was meant to assist authorities in forecasting the risk of lava flow events. The evolution of flows with time is best appreciated in the higher temperature range. The SAR data from ERS was used to derive a geocoded interferogram by pairing a 11 July 2001 scene with an 15 August 2001 scene. Details on the interferometric technique and applications are provided in Graham (1974), Zebker and Goldstein (1998), and Mahmood et al. (2003). The seismic activity started on 13 July 2001 and the first eruption took place two days later. The interferogram (Fig. 2b) with its well-organized colour fringes is indicative of significant terrain movement that accompanied the onset of the volcanic activity. As in many other cases of the Charter activation, routine monitoring of active volcanoes is believed to provide the critical benchmarks for assessing the effects of a disaster occurrence.

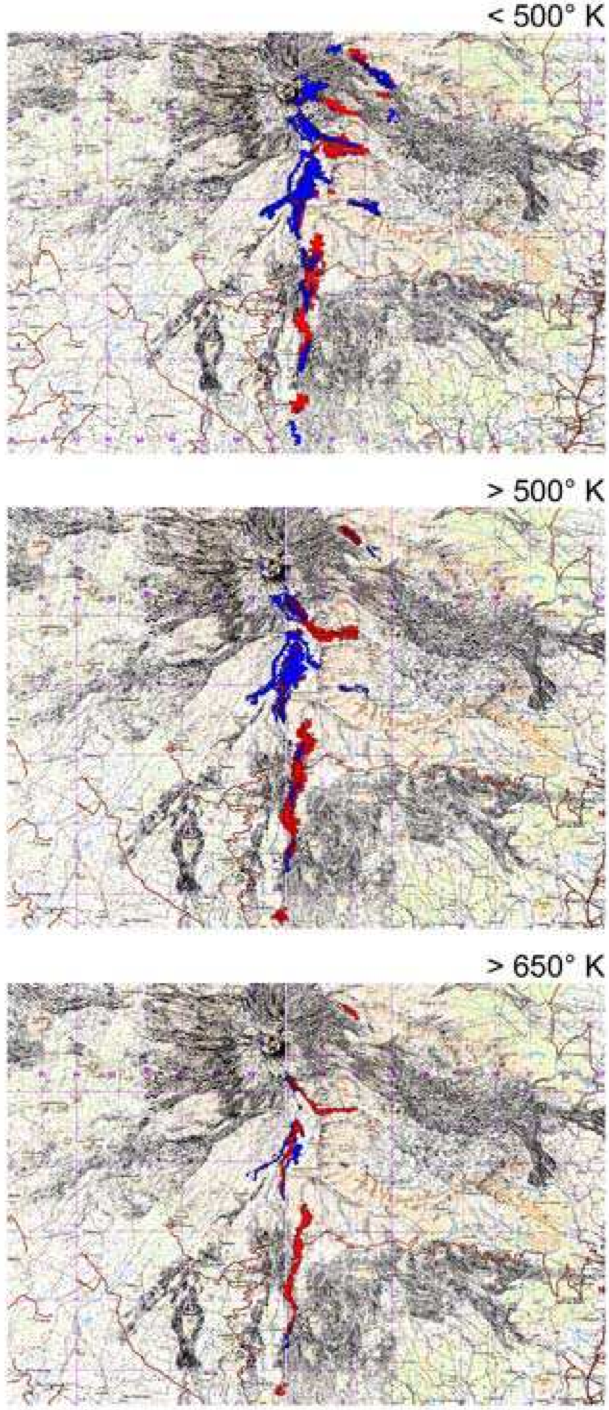

Fig. 2a. Etna volcanic eruption, Italy, 26 July 2001. Overall thermal anomalies were mapped for two dates, in blue (29 July, Landsat 7) and in red (21 July, Landsat 5) for assessing the risk of new vents. The analyzed radiance ranges were extracted by bands 7, 5 and 4. The evolution of flows with time, over the activation period is best seen on the map for flows $>650°$K.

4.2 Nyiragongo, Congo

Next, the Charter was activated on 21 January 2002 by the Belgian Civil Protection, when the Nyiragongo volcano in the Democratic Republic of Congo erupted and threatened

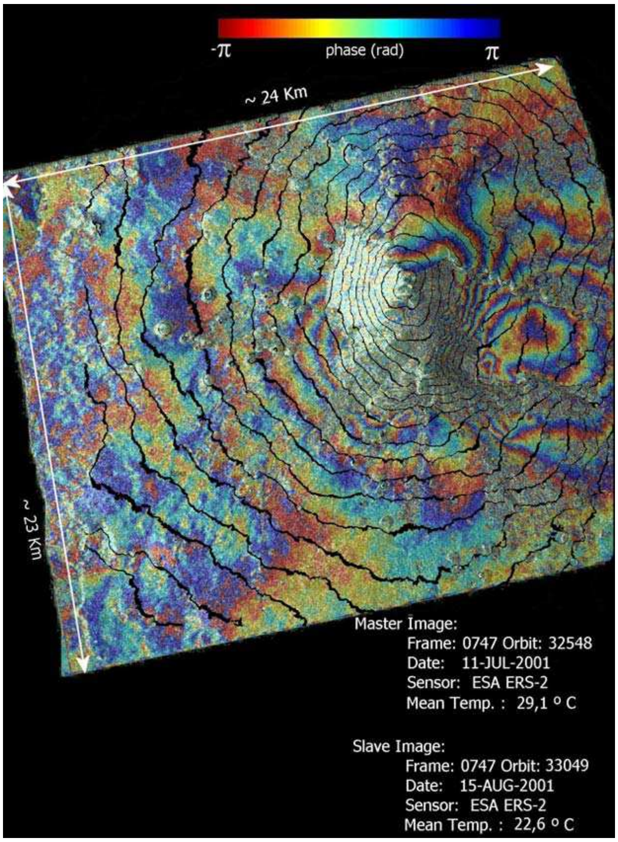

Fig. 2b. ERS data derived geocoded differential interferogram from 11 July 2001 and 15 August 2001 pairs. Seismic activity started on 13 July 2001 and the eruption on 15 July 2001. The well-defined fringes indicate important terrain displacement.

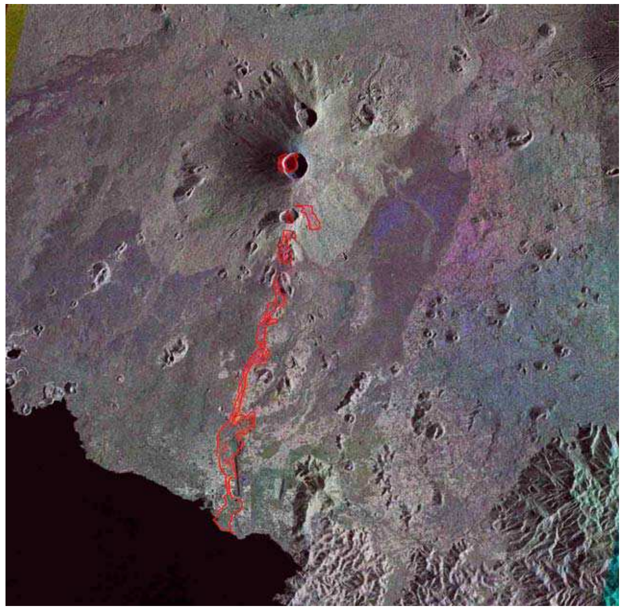

Fig. 3a. Nyiragongo volcanic eruption, Congo, 21 January 2002. Multitemporal composite of RADARSAT-1 images pre- and post-dating the disaster was used to delineate lava flow that invaded the city of Goma.

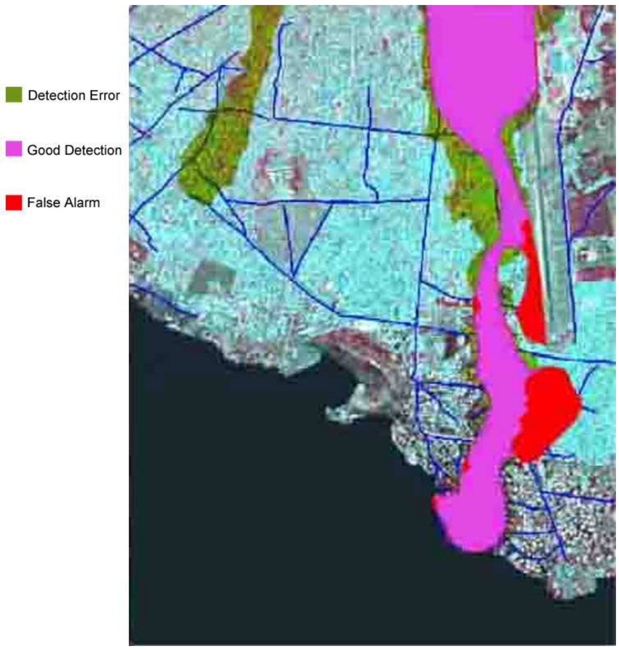

Fig. 3b. Nyiragongo volcanic eruption, Congo, 21 January 2002. Validation of satellite data-derived lava flows with ground truth on the city of Goma and its environs by using SPOT panchromatic and multispectral data for landcover and RADARSAT-1 Fine beam data for delineating the lava flow.

the city of Goma. Four Charter satellites, namely SPOT-2, SPOT-4, ERS-2 and RADARSAT-1 were tasked, but only RADARSAT-1 data were used for lava flow mapping because of the unacceptable levels of cloud cover in the optical imagery and some Doppler errors in the ERS data. Nonetheless, historical optical and ERS tandem mission data were used for image rectifications and for preparing the base maps. Figure 3a is a pre- and post-event RADARSAT-1 Fine beam composite, which was used to delineate the lava flow, as shown in red, and the lava flow area was then laid over a landcover map prepared with SPOT data (Fig. 3b) in order to identify the damage zones. The ground truthing of satellite data-derived lava flow maps revealed some discrepancies that are, however, acceptable in view of the rapidity with which information on a disaster event can be generated with space-based means. For example, experience has shown that even raw radar images can be used for lava flow mapping because of the sensitivity of radar brightness to the rate of lava solidification and moisture (Mahmood and Giugni, 2001).

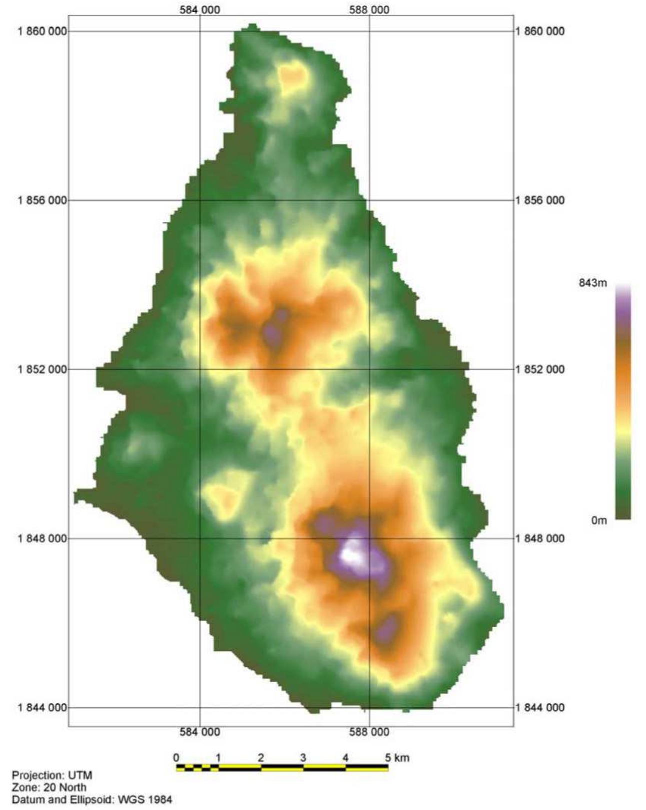

Fig. 4a. Soufriere Hills volcanic eruption, Montserrat, 18 July 2003. Radargrammetric digital elevation model (DEM) produced from Standard Mode RADARSAT data. Synoptics **(a)** of the Soufrière hills with crater zoom-in **(b)**.

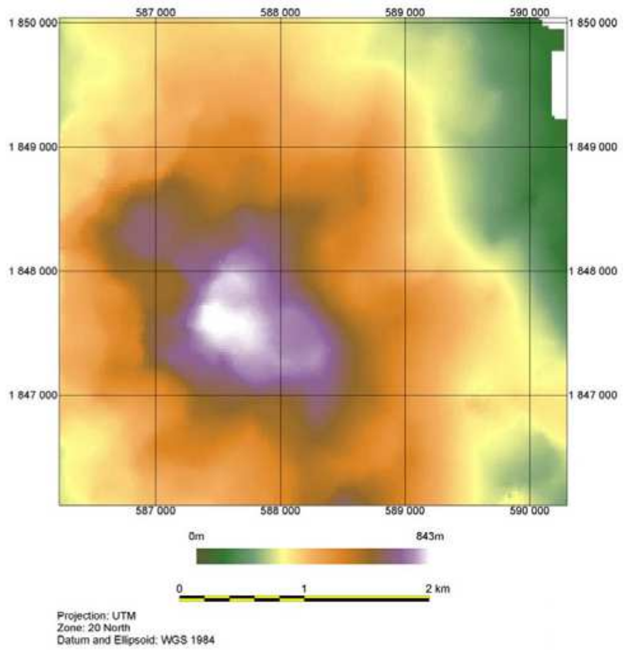

Fig. 4b. Continued.

4.3 Soufrière, Montserrat

The Charter was activated on 18 July 2003 at the request of the UK Department for International Development. The object of the Charter intervention was to produce for the end users in the Montserrat Volcano Observatory (MVO) and the Environmental Systems Science Centre of the University of Reading a new elevation model (DEM) to describe the changed topography of the volcano system following a series of eruptions in July 2003. Optical satellite data were ruled out for such an elevation model owing to the persistent cloud cover in the contemporaneous imagery. Radar interferometry, despite the higher accuracy of its products for detecting topographic changes, was also discounted because of the ground decorrelation effects caused by the shifting accumulations of ash and rainwater in the temporal datasets. A RADARSAT-1 multi-date colour-coded composite of the 1997 eruptive event was used to show the changes in radar image tone that could be induced by these accumulations. Consequently, for the purpose of this Charter activation, the DEM was generated by radargrammetric (radar stereo) technique and Standard mode RADARSAT-1 images were used. The DEM, synoptics of Soufrière Hills with crater zoom-in, is shown in Figs. 4a and b. The end users found the DEM results beneficial for calculating the volume of volcanic collapse as a result of the eruption. Moreover, additional mapping products, consisting of orthorectified radar imagery acquired soon after the eruption, provided the users with some indications of the changing crater structure. It may be noted that radargrammetry with RADARSAT-1 data employs beam-pair stereo, which is made possible because of the electronic beam steering capability of the satellite, the first of its kind among the imaging radars. Consequently, a target on the ground can be imaged at variable viewing angles according to the beam incidence selected (Mahmood et al., 1998; Mahmood and Giugni, 2002).

4.4 Galeras, Colombia

On 11 August 2004, the Galeras volcano erupted in a column of ash and gas. The Charter was activated by the Argentinean AU, SIFEM, to assist the Colombian Geological Survey, INGEOMINAS, with the monitoring of this eruption. Although optical SPOT-4, -5 and SAC-C images were planned, these could not be used because of the cloud cover and some other technical problems. The event was therefore managed by means of four RADARSAT-1 images acquired on both ascending and descending orbits in Standard 1, 2 and 6 beam modes. One of these was an archive image of May 1999 and the others were newly acquired images postdating the disaster. The images were co-registered using the 27 August acquisition. The 1999 RADARSAT-1 archive image and a Landsat TM mosaic of 1985/95 were used as reference for

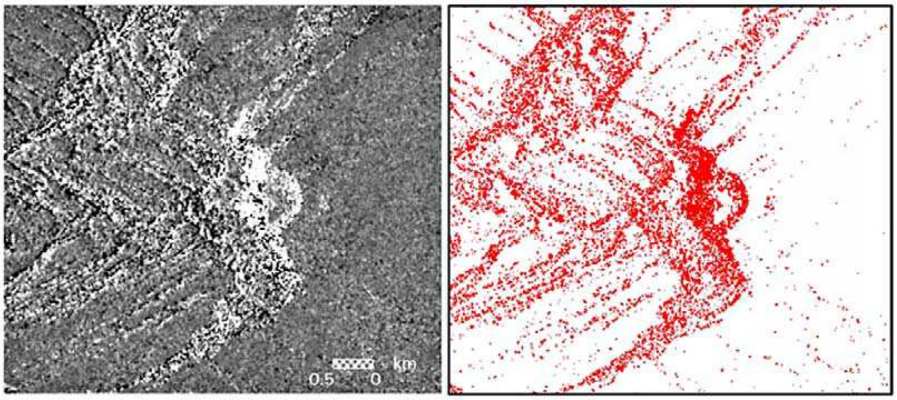

Fig. 5. Galeras volcanic eruption, Colombia, 25 August 2004. Change detection with composite RADARSAT-1 Standard beam images of 1999 and 2004, pre- and post-disaster acquisitions, based on the backscattering properties of the surface resulting in changes in the radar brightness of the two images.

Fig. 6a. Karthala volcanic eruption, Comoros, 1 December 2005. SPOT 4 data acquired on 13 July 2004. Bands 432 displayed as RGB; resolution 20 m.

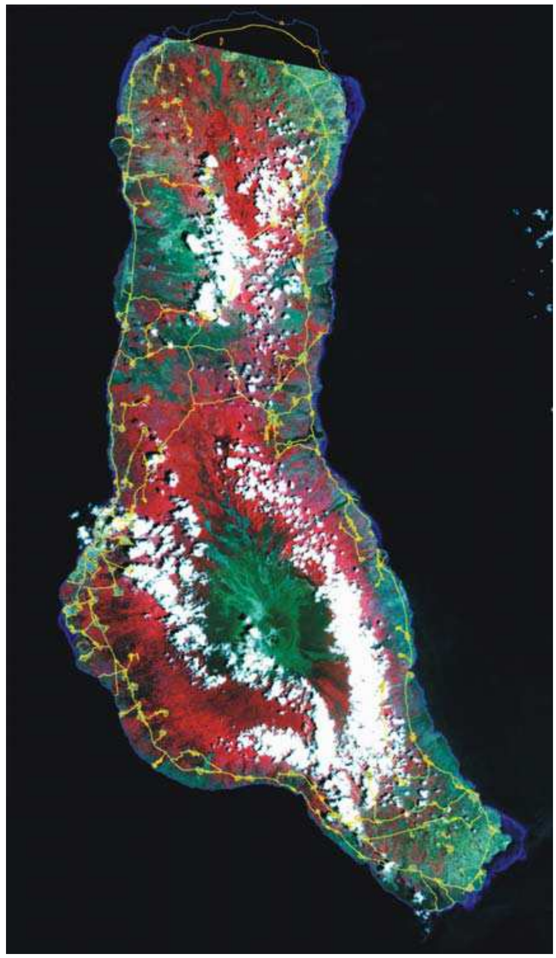

Fig. 6b. Karthala volcanic eruption, Comoros, 1 December 2005. SPOT 5 data acquired on 8 December 2005. Bands 432 displayed as RGB; resolution 10 m.

image interpretation and change detection. By stacking the 1999 RADARSAT-1 image with the newly acquired images, surface changes due to ash deposits could be marked (see Fig. 5). The RADARSAT-1 images also showed that the volcanic activity led to the formation of many fissures in the main crater and on the active cone. Radar layover and foreshortening did hamper image co-registration, however, the radar images accentuated the topographic contrasts around the crater area, and by means of the aforementioned Landsat mosaic, landscape visualization for monitoring the event and emergency planning by the local authorities was made possible.

4.5 Karthala, Grande Comore

The Charter was activated on 1 December 2005, by UN OOSA on the request of UNOCHA, UNDP (Resident Coordinator), and the French Red Cross following the eruption of Karthala volcano in the Comoros. Mount Karthala sent out clouds of ash and flying sparks, leaving the capital Moroni and other villages on the main island of Grande Comore covered in gray dust. There were concerns regarding the availability of drinking water in the areas exposed to smoke and ash. Earlier the Comorian government had also requested assistance in the absence of means to monitor the disaster by air and because of ground inaccessibility. Five Charter satellites were tasked, namely IRS, NOAA, RADARSAT-1, SPOT-4 and SPOT-5. The satellite data were exploited for change detection. In Fig. 6, damage assessment maps from the before-and-after-event RADARSAT-1 and SPOT images are presented. Figure 6a is a 13 July 2004 SPOT-4 20-m resolution band 432 RGB scene that depicts the old volcanic flow material around the crater, and Fig. 6b is an 8 December 2005 SPOT-5 10-metre resolution RGB scene showing the extent of new flows (in dull green) around the crater. For the sake of comparison, a RADARSAT-1 SAR 12.5-m resolution scene acquired on 5 December 2005 is presented in Fig. 6c. The main difference between the two data types is a significantly better detail of the crater following this latest eruption in the SAR scene than in the optical image. This is because of the inherently high sensitivity to textural and topographic contrasts of radar imagery.

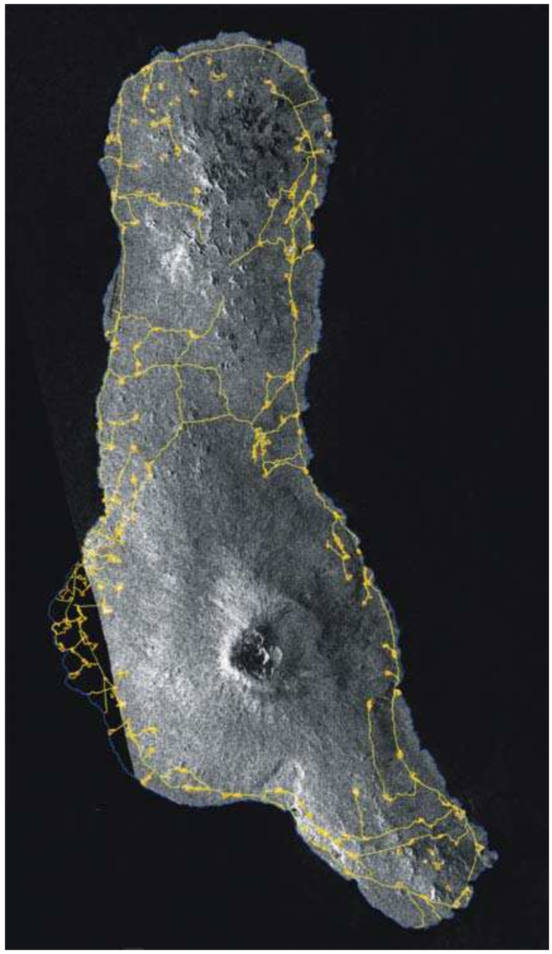

Fig. 6c. Karthala volcanic eruption, Comoros, 1 December 2005. RADARSAT-1 Standard beam mode data acquired on 5 December 2005 (resolution 12.5 m).

5 Conclusions

The International Charter aims at linking the space sector directly with the end users, such as the civil protection and emergency management organizations in the country affected by a disaster of natural or technological causes. The satellite data from a variety of sensors are acquired and processed and the information products are generated on a priority basis, with no cost to the user. The data and the derived products are particularly effective in the case of disasters related to volcanic eruptions. The first level of products can be readily generated for visualization with a combination of optical and radar data. The volcanic deposits can in fact be mapped with a high degree of accuracy directly on the appropriately acquired radar imagery. Further image enhancements furnish information on the structural changes in the volcanic edifice. Optical stereo and radargrammetric techniques have been used to quantify these changes. Radar interferometry has moreover provided indications on terrain deformation and seismic precursors for disaster warning.

The South and Central America region is particularly prone to disasters caused by volcanic eruptions, and the emergency response organizations of the countries of the region are geared towards disaster mitigation with the help of various ground, airborne and now space-based means. In order to help the concerned organizations with the use of satellite data, Project Managers from several Latin American countries were trained in September 2006, under the aegis of the Argentinean member of the Charter, CONAE, and were certified for performing this function. Currently, the establishment of a formal process of PM nomination is under way as another step toward streamlining the Charter operations in this part of the world.

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